Sludges

K/ET-5017

UCC-ND

H15-6.5
80:00009

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SOLID WASTE DISPOSAL STUDY

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May 21, 1980

APPROVAL FOR RELEASE

Document: # K/ET-5017 ; Date 5/21/80 ;
Title/Subject SOLID WASTE DISPOSAL STUDY

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KEY WORDS

Concrete Fixation, Cement, Sludge Handling, Sludge Dewatering, and Toxicity

ABSTRACT

Solidification studies conducted on sludge from the K-1407C Retention Basin confirm that cement fixation is a viable method for disposal of waste solids. A model is presented relating cement requirements and sludge moisture level to the final storage volume required for cement fixation. The sludge volume and ultimate disposal cost are strongly related to the moisture of the processed sludge. Dewatering efforts with the sludge using polymer dewatering aides and centrifugation are discussed.

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SUMMARY

The 1981 Line Item Project 81-R-506, Environmental Protection and Safety Modifications - Phase I, requires the development of solidification methods to permanently dispose of sludge. Among the sludge disposal methods presently available are fixation with polymer, asphalt, glass, calcium-silicate, or cement. A review of these methods and characterization of the sludges has been reported by McGinnis.[1] Because cement fixation is a straight forward and well recognized waste disposal technique, this method was chosen as the preliminary design basis for the conceptual design of this project.

The solid waste at ORGDP should be converted into a form that will be easy to store, will be of a permanent nature, and could be recoverable at a later date if necessary. To withstand the abuse of handling equipment and to meet toxic waste criteria, the waste in the fixed form should have an ultimate compression strength greater than 300 psi. The strength is determined by a structural integrity testing procedure included in the EPA guidelines.[2]

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This paper describes the solidification studies performed on sludges from the K-1407C retention basin. These studies were made to determine the optimum operating range of the Central Sludge Treatment Facility and to evaluate cement fixation as a method of sludge disposal. The critical parameters studied were ultimate compression strength and toxicity leachate levels.

Because costs were felt to be related to final storage volume, the effect of the sludge moisture content on the volume of the waste after cement fixation was also determined. It was found that dewatering the sludge from the nominal sludge moisture content of 60% or greater to a moisture content of 40% reduced the final concrete volume by 44%. Further dewatering was found to be unnecessary since additional water would then be required for cement hydration.

A mathematical model was developed to quantify the major parameters and to serve as a design basis for the Central Sludge Treatment Facility. A model allowing the calculation of the cement requirements to obtain a given strength is presented. This model shows the strong correlation that exists between the water/cement ratio and the strength of the cured concrete. A relationship showing the sludge density as a function of the sludge moisture level was developed. These functions are combined in a comprehensive model which permits determination of a final waste volume as a function of cement addition, sludge moisture, and strength requirements.

The following conclusions are drawn from this study:

1. The cement-fixed waste passes the EPA standard leach test for toxic substances;

2. The addition of cement improves the handling characteristics and produces a permanent monolithic waste which could be reclaimed if necessary;

3. A structural strength of 300 psi, which provides adequate permanency, can be obtained with little increase in volume by adding cement; and

4. Dewatering sludge significantly reduces the cement requirement and landfill space requirement for sludge disposal.

EXPERIMENTAL AND RESULTS

Final strength of the fixed material is determined by laboratory testing according to ASTM C513-69. For this test the grout is cast in 2-in. cubes and is cured for 28 days in a constant humidity environment. Strength is calculated by measuring the yield strength per unit area of the specimen. Compressive strength is the governing parameter for industrial concretes and has proved useful in conducting this solidfication study.

Table I

LEACH TEST RESULTS

		(μg/ml except as noted)		
Toxic Elements	EPA Guidelines†	Concrete w/c = 4.1	Concrete w/c = 3.2 With Polymer	Dried Sludge
Arsenic	0.50	< 0.005	< 0.005	< 0.05
Barium	10.0	< 0.30	< 0.30	0.75
Cadmium	0.10	< 0.05	< 0.05	< 0.05
Chromium	0.50	< 0.05	< 0.05	0.06
Lead	0.50	*	*	*
Mercury	0.02	0.0005	0.0001	0.022
Selenium	0.10	< 0.005	< 0.005	0.007
Silver	0.50	< 0.05	0.05	< 0.05
Uranium	45††	0.008	0.014	1.260
Technetium, μCi/mℓ	1×10^{-2}††	$< 4.5 \times 10^{-6}$	$< 4.5 \times 10^{-6}$	$< 6.7 \times 10^{-6}$

†EPA Guidelines, see Reference 2.
*Previous lab sample results report no detectable lead.
††DOE Guidelines, see Reference 4.

Sludge at the test moisture level is blended in a laboratory mixer, Figure 1, to achieve a homogeneous mix. The resulting concrete is placed in thin layers into a mold attached to a vibrating table. This allows any voids caused by trapped air to be filled. The loaded molds are smoothed by trowel after vibrating for 10 min. The molds and vibrating table are shown in the photograph of Figure 2. The molds are then placed in a sealed container at 100% humidity for 24 hr. The samples after initial curing are wrapped with a water-impermeable wax paper, Parafilm M, and allowed to set during the 28 day curing period.

STRENGTH MODEL DEVELOPMENT

Compressive strength for several runs at various sludge moisture levels are plotted against the water-to-cement ratio (w/c) as shown in Figure 3. The w/c is a common strength determinant in concrete formulation. The points are adequately modelled by the hyperbolic equation

$$\text{Strength} = 2088/(w/c) - 377 . \qquad (1)$$

Transformation of the equation by substitution of the term c/w for 1/(w/c) results in the following linear equation:

$$\text{Strength} = 2088(c/w) - 377 . \qquad (2)$$

A plot of Equation 2 is shown in Figure 4. The correlation coefficient for the model is $R^2 = 0.995$. Dewatered and cured sludge with no cement addition gave strengths of 17 to 284 psi. This material rewet easily when exposed to moisture and is not suitable for disposal.

TOXICITY TEST RESULTS

Under the Environmental Protection Agency's proposed guidelines for the identification of hazardous wastes,[2] a waste is considered hazardous if it is listed as a part of the guidelines or if it is ignitable, corrosive, reactive, or toxic. Although the wastes studied in this project are generally not ignitable, reactive, or corrosive, toxic substances are present in the sludge. The Environmental Protection Agency requires that a specific laboratory leach test be performed and that the leachate have concentrations of specified metals less than 10 times the drinking water standards to be considered nontoxic. Testing of the solids in this study for the leaching of toxic substances indicated that wastes solidified with various levels of cement meet the EPA quidelines.

In this extraction procedure, the sample cube is added to 16 times its weight of water and held at a pH of 5 for 24 hr. Then, the amount of water is increased to 20 times the sample's weight. After the cube is removed, the water is analyzed for the presence of the eight specified toxic elements. Test results are compared with the EPA guidelines in Table I. Although the results of only three samples are shown in Table I, the tests showed that the leachates from all of the cement-fixed samples were within the EPA limits.

Figure 1

LABORATORY PREPARATION OF CONCRETE MIXTURE

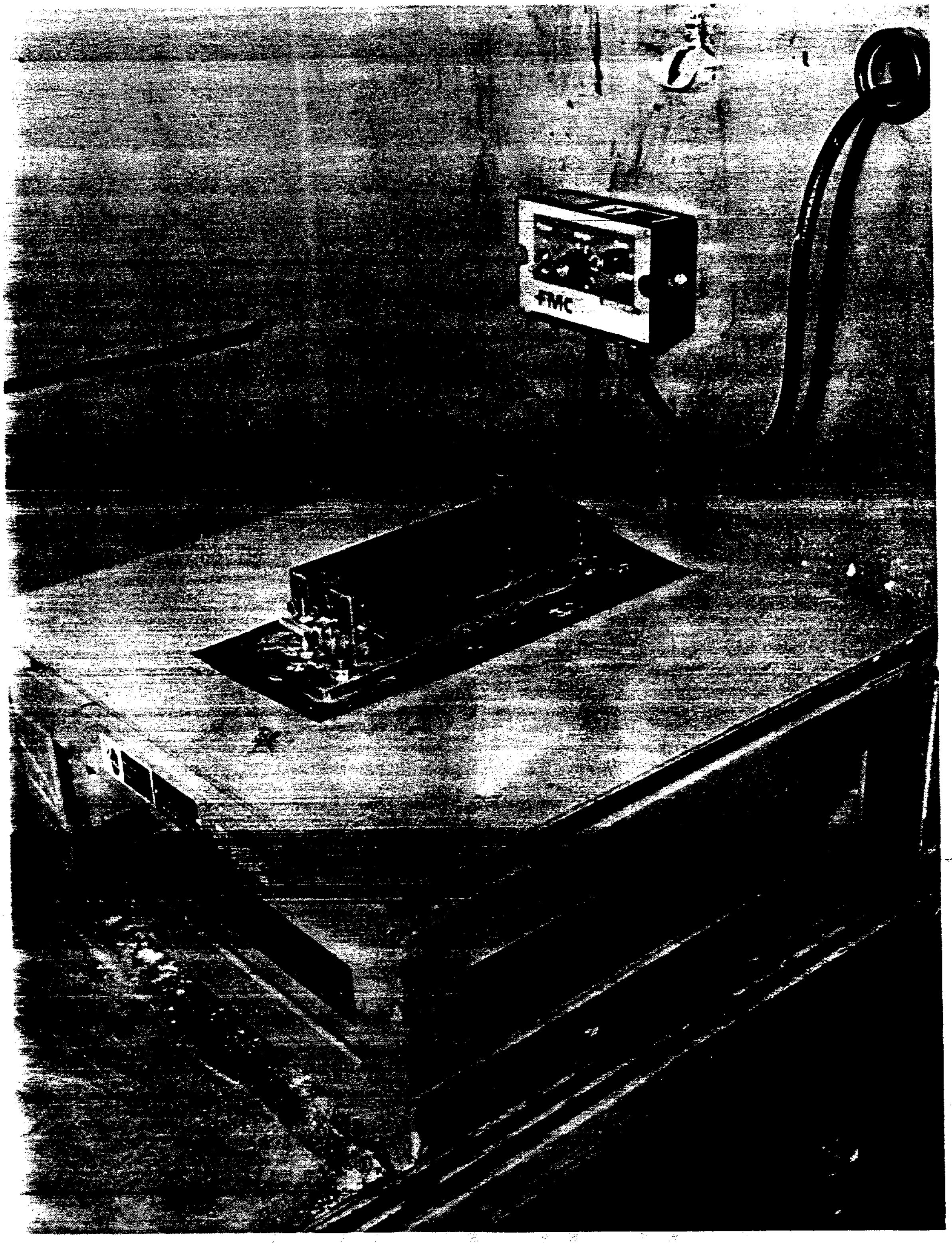

Figure 2

ASTM CONCRETE MOLD MOUNTED ON VIBRATING TABLE

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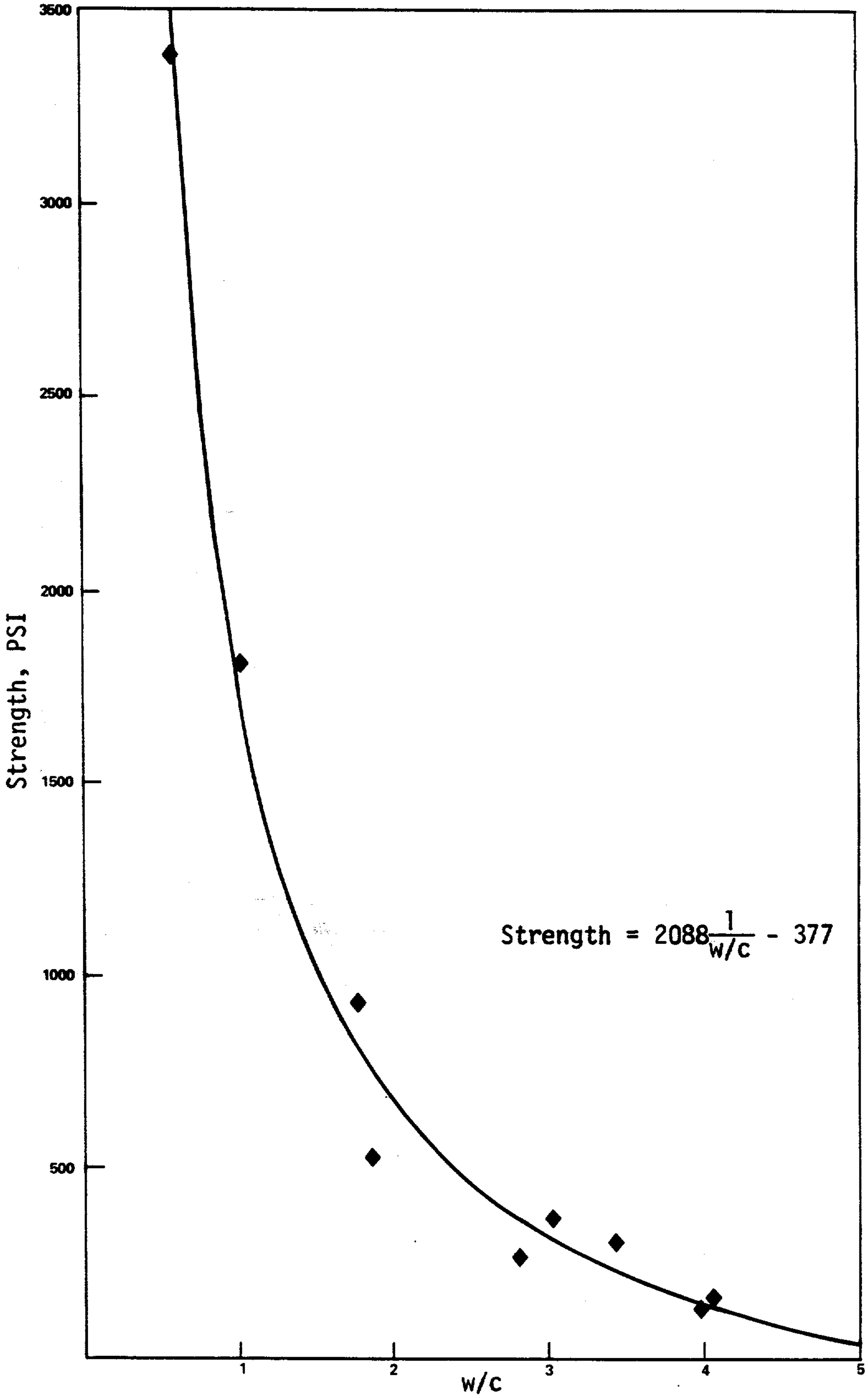

Figure 3
HYPERBOLA FOR w/c VS. STRENGTH

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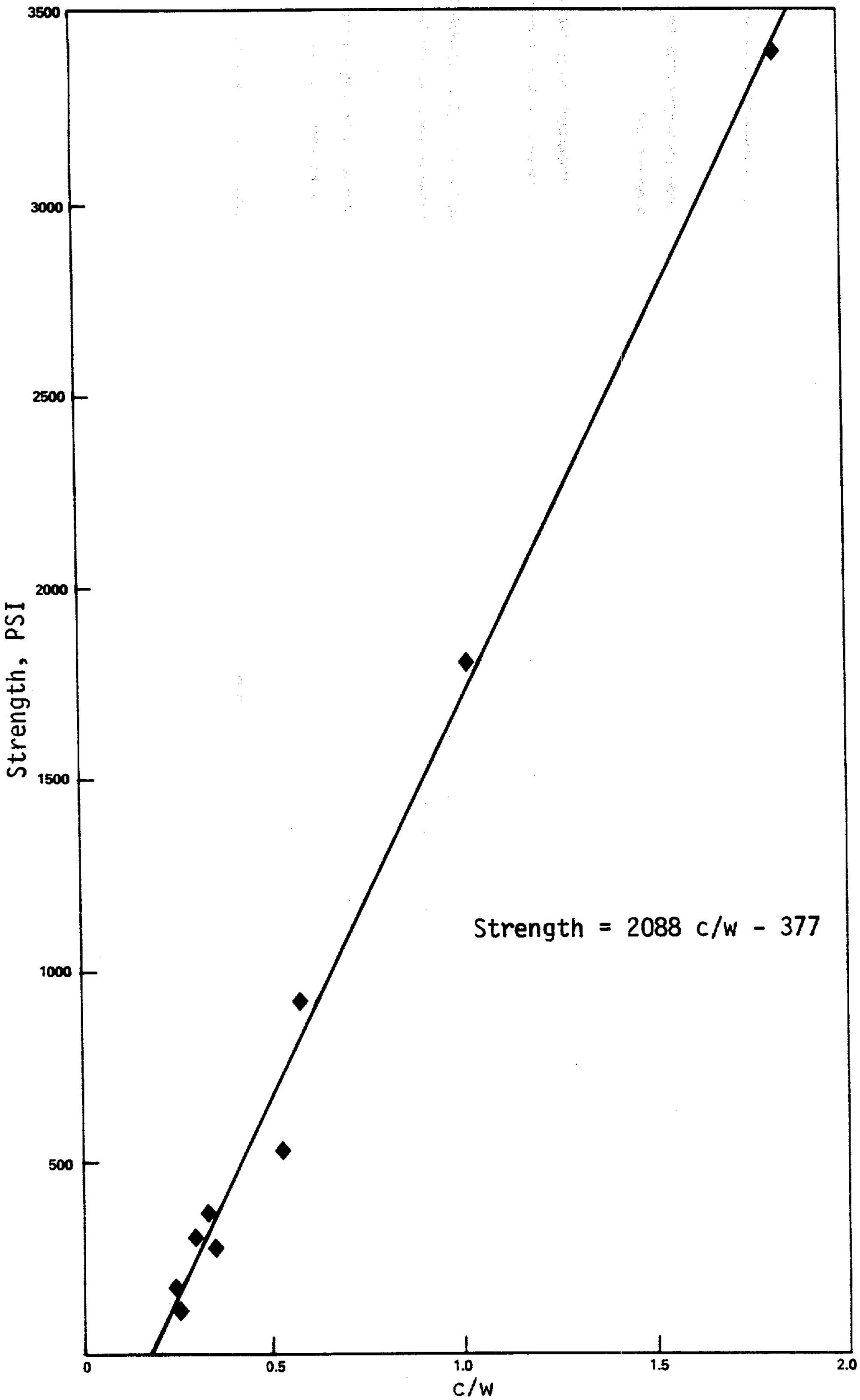

Figure 4
STRAIGHT LINE FOR c/w VS. STRENGTH

Toxicity leaching tests were also performed on a sample of dried sludge with no cement added. The leachate from this sample also passed the toxicity test except for mercury, but it disintegrated during the structural integrity test and formed sludge when rewetted. Thus, although the addition of cement is not necessary to prevent the leaching of most of the toxic elements, it is needed to give the sludge sufficient strength to survive handling during disposal and to allow retrieval if desired in the future.

Tests were performed to learn if the polymer used to dewater sludge would have an adverse effect on the toxic extraction test results. As shown in Table I, the leachate levels for all of the elements tested were very similar to those for the samples with no polymer.

SLUDGE SOLIDS DENSITY

The strength model developed in Figure 4 is independent of sludge moisture content. Sludge as received from the K-1407C Retention Basin can be fixed over the moisture range of 35% to 100%. The volume of the final cement-encapsulated sludge is a function of the sludge moisture content. The final volume should be minimized to conserve landfill space and cement requirements.

Densities of sludge at several moisture levels were measured. The calculated dry density of the sludge is 2.24 g/cm^3. These density measurements are plotted in Figure 5. A hyperbola of the form

$$y = \frac{2.24}{1 + 1.24x} \qquad (3)$$

where y = Density of the wet sludge in g/cm^3, and
x = Sludge moisture level in % ,

forces the model to meet the boundary conditions of dry density of 2.24 g/cm^3 and 100% moisture density of 1.0 g/cm^3. Good fit is noted in Figure 5. The model correlation coefficient is $R^2 = 0.89$.

ANALYSIS OF DENSITY AFTER CEMENT ADDITION

By combining the density model with the strength vs w/c model, a composite model to define fixed sludge density at constant strength can be developed. Figure 6 presents the final model. Specification of final strength and sludge moisture level allows determination of the sludge density. The utility of the model can be illustrated by considering two examples.

Example 1: The sludge has a 60% moisture content (point A on the graph). To fix this sludge in concrete having a w/c of 2.5 (strength of 450 psi), cement must be added to make it approximately a 19.5% constituent. This cement addition gives a dry concrete density of 0.47 g/cm^3 as shown by point B.

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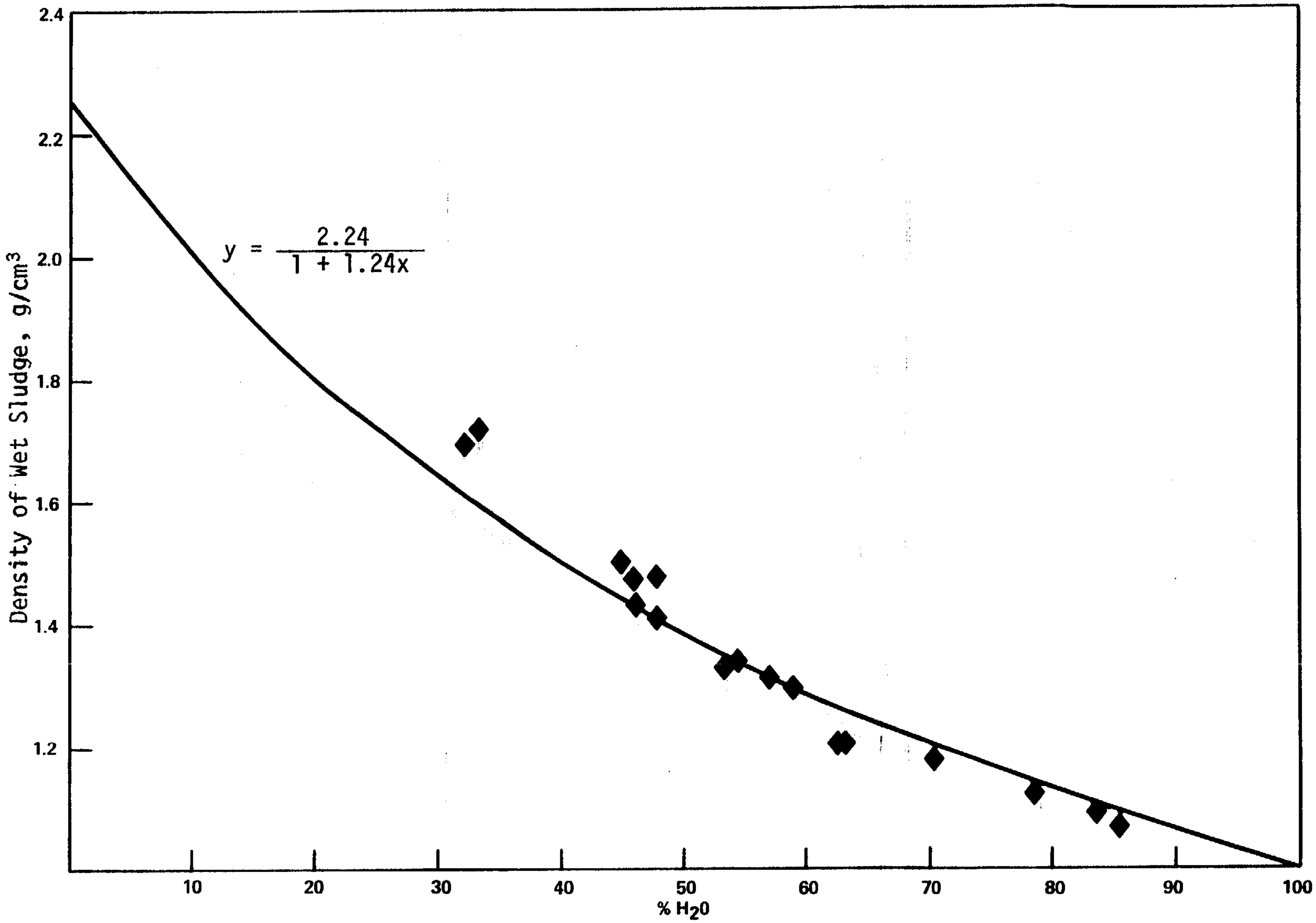

Figure 5

THEORETICAL CURVE FOR DENSITY OF WET SLUDGE VS. % MOISTURE
Experimental points from Table VI are shown on curve as ◆'s.

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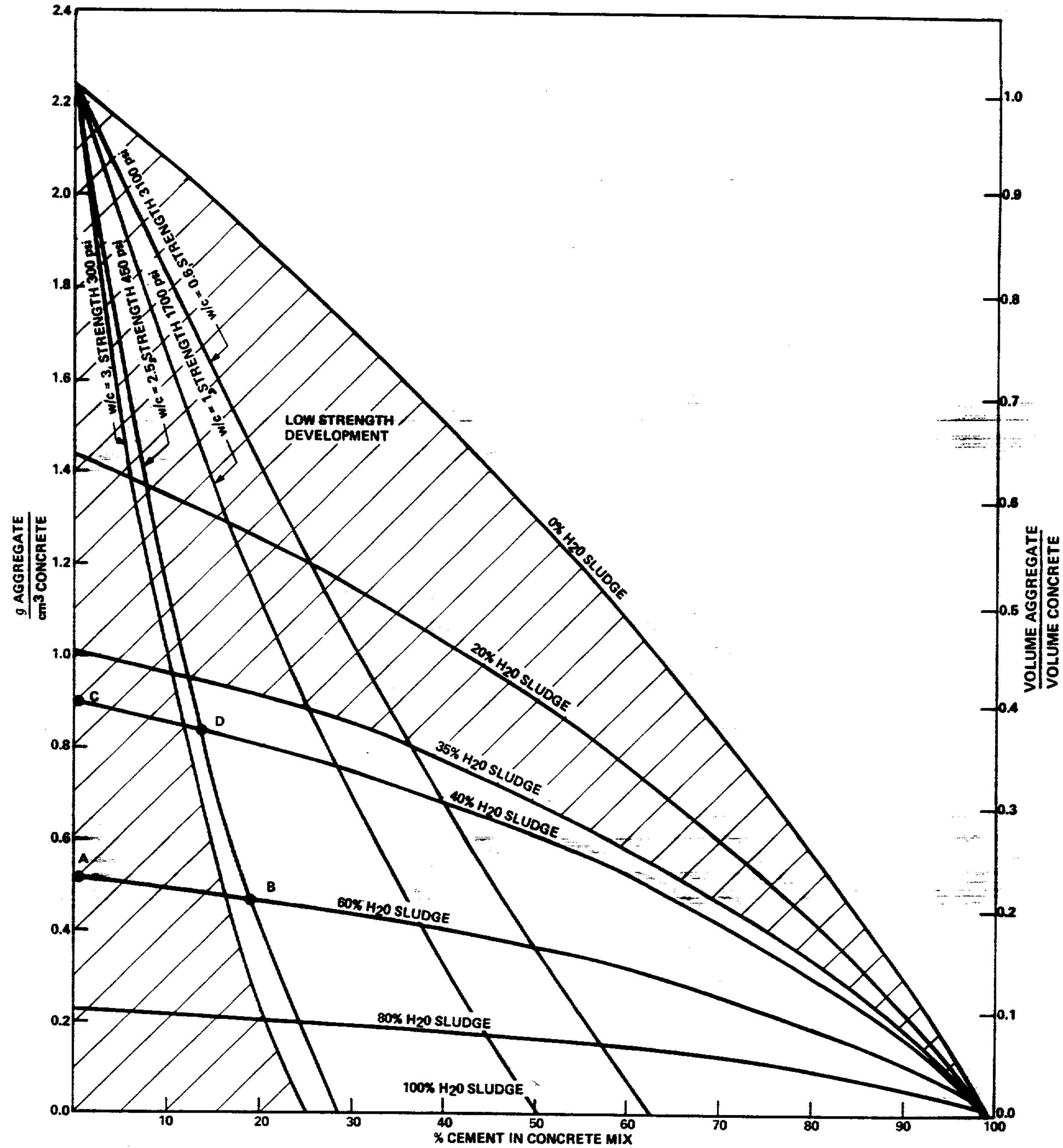

Figure 6

DENSITY ANALYSIS CURVES

Example 2: If the sludge in Example 1 is first dewatered to a 40% moisture content, point C, then mixed with cement, as shown by point D, to give the same w/c (strength) as in the example above, the resulting dry concrete density is 0.83 g/cm^3. Dewatering the sludge from 60 to 40% then adding cement increases the density of the concrete by

$$\frac{0.83 - 0.47}{0.47} \times 100 = 76.6\%,$$

and decreases the volume to be disposed of by

$$(1 - \frac{1}{1.766}) \times 100 = 43.4\%.$$

Dewatering the sludge with no addition of cement from 60 to 40% moisture increases the density of the wet sludge by

$$\frac{0.89 - 0.51}{0.51} \times 100 = 74.5\%,$$

and so decreases the amount of wet sludge to be handled by

$$1 - \frac{1}{1.745} \times 100 = 43\%.$$

It is interesting to note that dewatering before addition of cement significantly decreases the volume of waste to be disposed of while increasing the strength. For the case described in Example 2, the fixation method increased the density from 0.51 g/cm^3 (wet sludge density) to 0.84 g/cm^3 (concrete density) while decreasing the volume of the waste by 39.2%. By using the fixation method developed in this project, the resulting volume is only 16% of the volume produced using the tentative recipe given in the conceptual design report.

CONCLUSIONS

The following conclusions are drawn from this study:

1. The cement-fixed waste passes the EPA standard leach test for toxic substances;

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1. C. P. McGinnis, "Solid Waste Disposal Study," *Compilation of papers Presented at the 1979 UCC-ND Waste Management Seminar, March 6-7, 1979 (U);* Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee; March 1979 (K/C-1347).

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